Mobile-Assisted Network Location System (MNLS) Overview

Marc Sather, John Snapp and Alan MacDonald

AT& T Wireless Services
Technology Development Group
March 30, 2001

Introduction:

Mobile-assisted Network Location System (MNLS) is a network-based technology that utilizes signal strength measurements made by the wireless handset to determine the location of the mobile while on an emergency (911) call. AWS has been investigating MNLS for possible use for Phase II E911 service since 1997. During this time we have conducted, participated in or reviewed multiple trials and simulations on TDMA technology networks. As outlined below, MNLS appears to offer significant advantages to all TDMA customers in terms of:

- based on existing and well known TDMA functionality,
- no need for handset upgrade or replacement
- ubiquitous service to all customers (including roamers),
- superior reliability (due to integral nature of the solution within overall network)
- consistency with TR45.2 AHES standards.
- potential swiftness of implementation due to minimal development

Overview:

The MNLS technique makes use of an existing mechanism of TDMA IS-136 and IS-54B handsets, in which the mobile handset makes measurements to assist the wireless system in determining the best cell site to handoff the mobile. In this technique, often referred to as MAHO (mobile-assisted handoff) the mobile is commanded by the wireless system to make signal strength measurements of up to 24 neighboring base stations. The mobile makes these measurements on the continually transmitting strong control channel broadcast from each base station sector to the mobile. In TDMA, the MAHO list is controlled by the operator, and makes measurement on every MAHO candidate channel regardless of signal strength. This provides a list of the broadcast power from multiple cell sectors to a mobile in its current position. Since the MAHO measurements can be made down to the minimum sensitivity level of the phone (-113 dBm), the mobile is able to "hear" sites within a large radius.

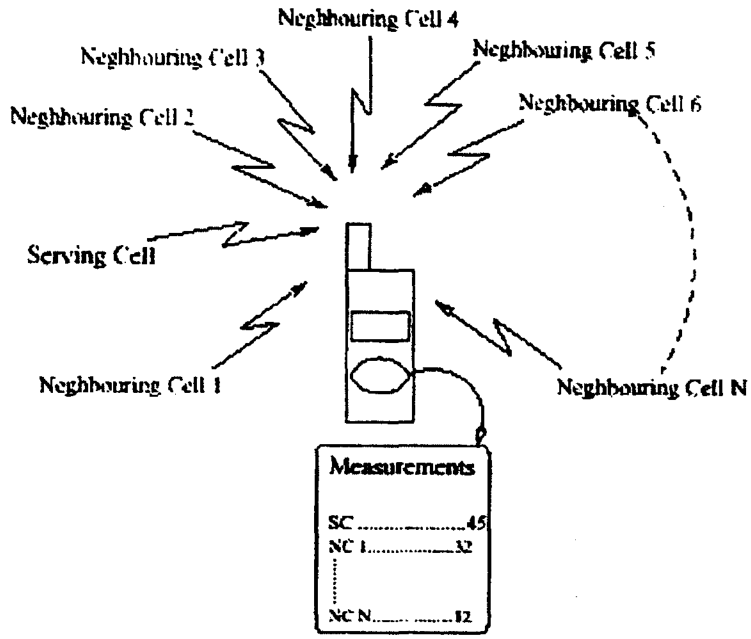


Figure 1: Mobile measures neighboring base stations signal strength

After making these signal strength measurements, the mobile will transmit these reports back to the wireless system. These reports will be sent to the position determining equipment (PDE) while the 911 voice call is being setup to the PSAP. (Note: The 911 call is not held or delayed prior to call setup.) Unlike some other network solutions, an advantage of the MNLS system, is that MAHO reports are transmitted from the phone every 1 second during a TDMA call, consequently, this technology could provide the ability to track the 911 call, rather than just an initial location at call setup.

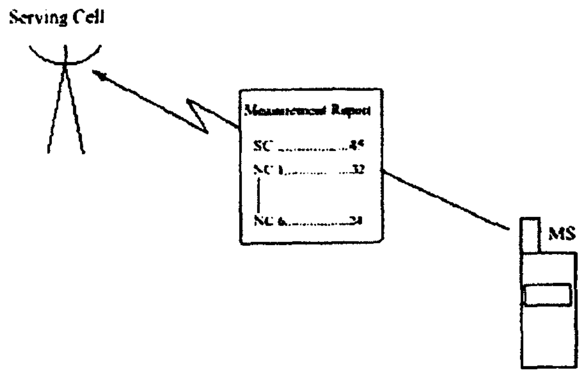


Figure 2: Mobile reports the measurements it made back to the wireless system

The MAHO lists and cell site information are delivered to a processor that can determine mobile location with either, or a combination, of two techniques. AT&T Wireless will initially utilize the second ("contour matching") technique, but will investigate the possibility of using the first ("triangulation") technique, either in place of or in combination with triangulation, as a means for improving accuracy.

In the first technique, termed "triangulation", the signal strength from multiple MAHO channels is associated to their cell site location. This then produces a geometric triangulation mathematical problem that can be solved to determine the mobile's location.

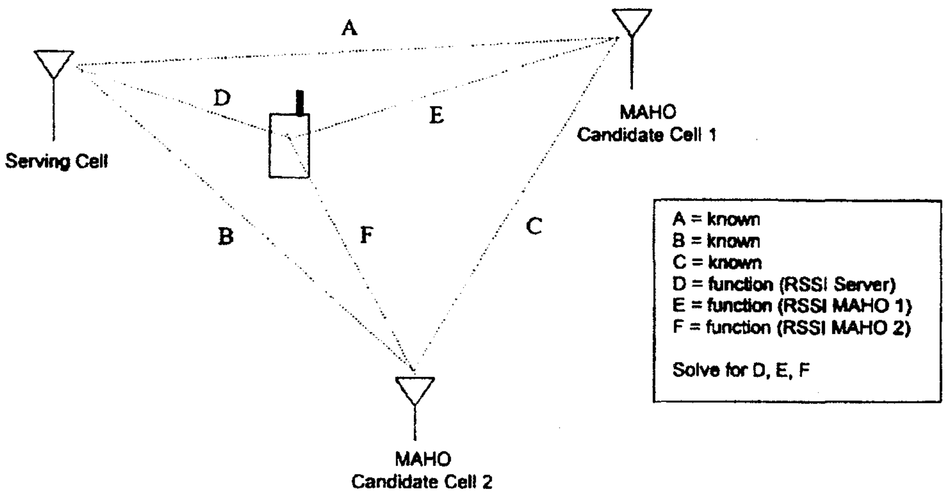


Figure 3: Example of "triangulation" to determine location, 3 site example.

In the second technique, termed "contour matching", the wireless system receives these measurements and compares these relative signal strength measurements to a specially-developed database of stored relative signal strength measurements within the cell serving the call. The wireless system will then determine the location of the mobile by matching it to one of these predetermined grid locations in the database.

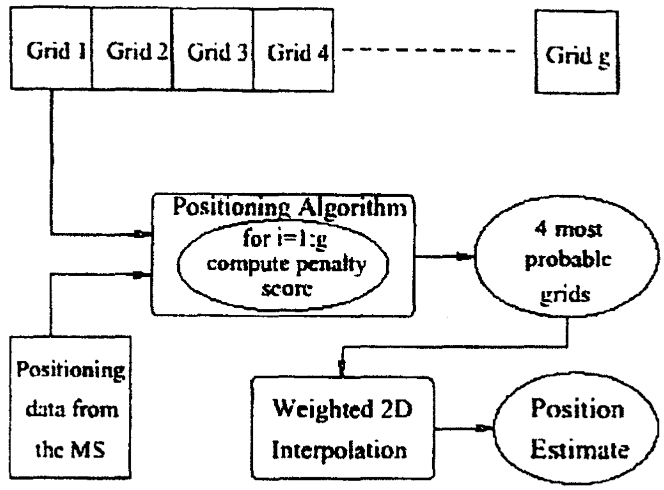


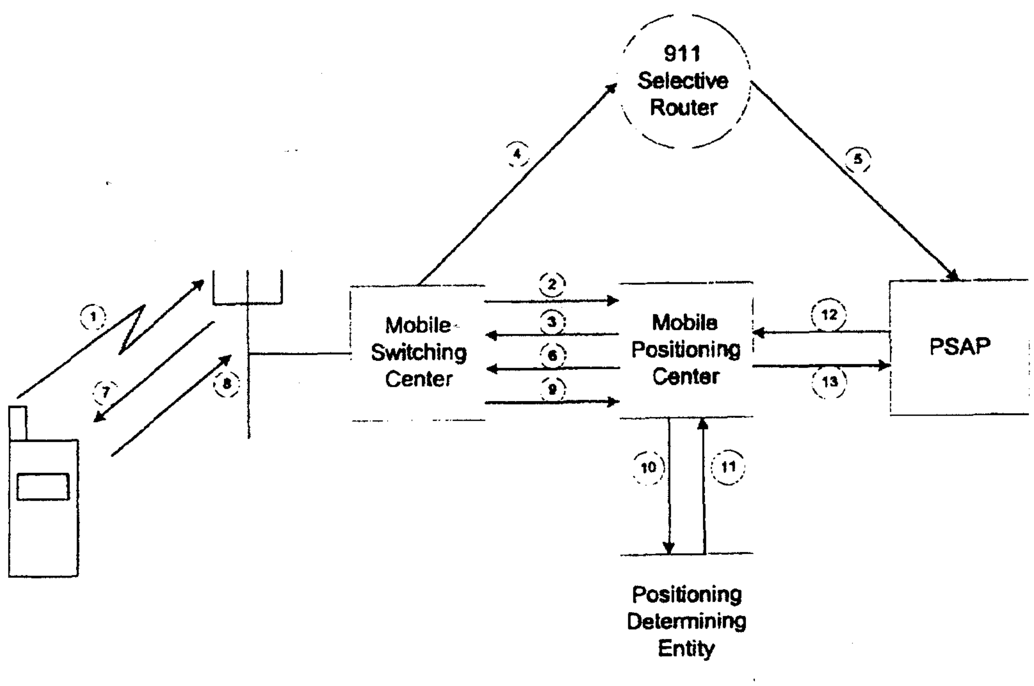
Figure 4: Wireless system determines location by matching DB grids to mobile report

The database for the grid measurements can be created in several different methods. The best method is to use available RF engineering tools to predict the expected received signal strength (RSS) measurements within grids as small as 50 meters. These engineering tools take into account antenna height and type, down-tilt, beam width, effective radiated power, and ground clutter. These predictive measurements can then also be augmented with real world measurements to increase accuracy in difficult areas.

It is possible to use both the triangulation and contour match techniques in combination. In combination, it would allow for the most flexibility.

Overall Location Processing Flow:

The following is the flow of the call through the network.



1. The mobiles places a call to 911
2. The MSC sends a J-STD-036 compliant message to the MPC indicating that a 911 call was placed, that the MSC is capable of doing MNLS and that the mobile is TDMA.
3. The MPC returns routing instructions to the MSC directing the call to the proper PSAP.
4. The MSC routes the voice portion of the call to the Selective router.
5. The selective router routes the call to the proper PSAP.
6. The MPC queries the MSC for the signal strength measurements, using a J-STD-036 compliant message, necessary for MNLS.

7. The MSC commands the mobile to make the measurements.
8. The mobile responds with the measurement report.
9. The MSC forwards the measurement report to the MPC.
10. The MPC sends the measurement report to the PDE to compute the exact location.
11. The PDE matches the location of the caller within the grid of the serving cell and returns the X/Y of the caller to the MPC.
12. The PSAP queries the MPC for the location of the call that it has just received.
13. The MPC returns the location of the caller to the PSAP.

(Steps 6-13 can be repeated for additional updated locations. Note: One of the advantages of the MNLS system is the fact that locates can be completed repeatedly on the same 911 call, in order to allow PSAPs additional information, such as direction of travel, etc.)

Status of Standards Efforts:

MNLS is a fully standards-compliant solution that is currently being adopted by TR45.2 AHES (Ad-Hoc on Emergency Services), the industry-PSAP body overseeing wireless E911 standards.

Advantages:

The MNLS has many advantages over other alternate solutions investigated. These advantages include:

1. Legacy handsets – The systems works with all TDMA handsets in the AWS ANSI-41 network. No changes, upgrades or replacements are necessary to these handsets.
2. Roaming support – MNLS will support all TDMA handsets roaming into our network.
3. Non-valid/uninitialized handsets – MNLS will support TDMA phones that do not have a valid account or phone number.
4. High Reliability – MNLS is using the same functionality normally required by the network. Therefore, if problems arise, they will be detected immediately. The integral nature of the MNLS solution to the overall network dramatically increases the reliability of the system. [Note: Conversely, network-overlay solutions, which by definition are independent from the normal call flow, make problems very hard to detect due of very low 911 call volume (relative to non-emergency calls). Trial experience has demonstrated that a complex low traffic system is extremely difficult to properly maintain and in which to detect problems.]
5. Standards compliant – MNLS is a fully standards compliant (see above).
6. Updated Location – One of the advantages of the MNLS system is the fact that locates can be completed repeatedly on the same 911 call, in order to allow PSAPs additional information, such as direction of travel, etc.

7. Improvement – The accuracy of the system can most likely be improved with ongoing enhancements to the algorithms, and to the location grid database.
8. One of the advantages of the MNLS system is the fact that locates can be completed repeatedly on the same 911 call, in order to allow PSAPs additional information, such as direction of travel, etc.

Trials:

AWS has been investigating MNLS since early 1997 as a possible solution to locating E911 callers. We have conducted, participated in or reviewed multiple trials including the following:

1. Trial in Kirkland, WA by AT&T Wireless in 1997
2. Trial by Nortel Networks in 1998
3. Trial in Stockholm by Ericsson in 2000
4. Trial in Redmond, WA by AT&T Wireless in 2001

Accuracy:

The following are the approximate accuracies expected:

All Environments	67%	95%
All Calls	Approx. 250 meters	Approx. 750 meters

EXHIBIT 2

ORIGINAL

RECEIVED

JUN 1 4 2001

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

EX PARTE OR LATE FILED

AT&T

Douglas I. Brandon
Vice President-
External Affairs & Law

AT&T Wireless Services, Inc.
Fourth Floor
1150 Connecticut Ave., N.W.
Washington, DC 20036
202 223-9222
FAX 202 223-9095

June 14, 2001

HAND DELIVERY
Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Notice of Ex Parte Presentation
Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems

CC Docket No. 94-102

Dear Ms. Salas:

On Wednesday, June 13, 2001, Karl Korsmo, Lori Buerger, Alan McDonald, and John Snapp of AT&T Wireless Services, Inc., Stephen Meer of Intrado (formerly SCC Communications), and the undersigned met with Kris Monteith, Blaise Scinto, Dan Grosh, Pat Forster, Jennifer Tomchin and Marty Liebman of the Wireless Telecommunications Bureau to discuss AT&T Wireless's proposed MNLS technology for Phase II compliance on its TDMA air interface. A copy of the AT&T Wireless E-9-1-1 Phase II MNLS Solution hand-out distributed at the meeting is attached.

Pursuant to sections 1.1206(b)(1) and 1.1206(b)(2) of the Commission's rules, an original and one copy of this letter and attachment are being filed with the Office of the Secretary. Copies are also being served on the Commission personnel in the meetings.

Respectfully submitted,

Douglas I. Brandon BTB

Douglas I. Brandon

cc: Kris Monteith
Blaise Scinto
Dan Grosh
Pat Forster
Jennifer Tomchin
Marty Liebman

No. of Copies rec'd 0+1
List A B C D E

WDC 215732v1

Recycled Paper

AT&T Wireless E9-1-1 Phase II MNLS Solution

AT&T Wireless

- Doug Brandon – VP, Ext. Affs.
- Karl Korsmo – VP, Ext. Affs.
- Lori Buerger – Director, Ext. Affs.
- Alan MacDonald – Director, RF Strategy,
  Technology Development Group
- John Snapp – Consultant, former
  Vice-chair TR45.2 AHES
- Stephen Meer – CTO, Intrado (formerly
  SCC Communications)

Agenda

- Overview of MNLS
- MNLS advantages to Public Safety
- MNLS trials
- Parallels to RF Fingerprint
- Paths to improved MNLS accuracy
- Keys to success
- Intrado's role and perspective

AT&T

Mobile-assisted Network Location System (MNLS)

MNLS is a RF pattern-matching location technique that utilizes existing functionality of the TDMA system

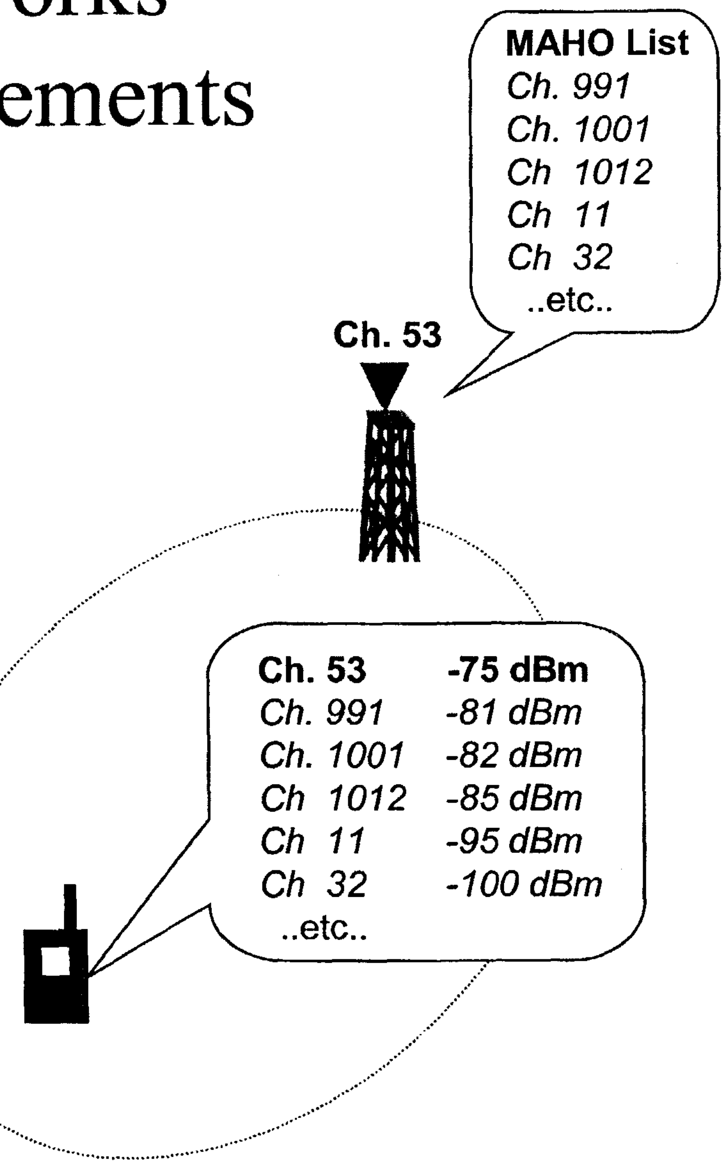
•MNLS is a technology that utilizes signal strength measurements made by the handset to determine the location of the mobile while on an emergency call.

• The MNLS matches the RF signal strength reported by the mobile to a stored database of measured and predictive measurements, to calculate the most likely position of the mobile.

•The MNLS requires no handset changes and uses standardized IS-136 "mainstream" functionality (MAHO) which is core to the wireless system.

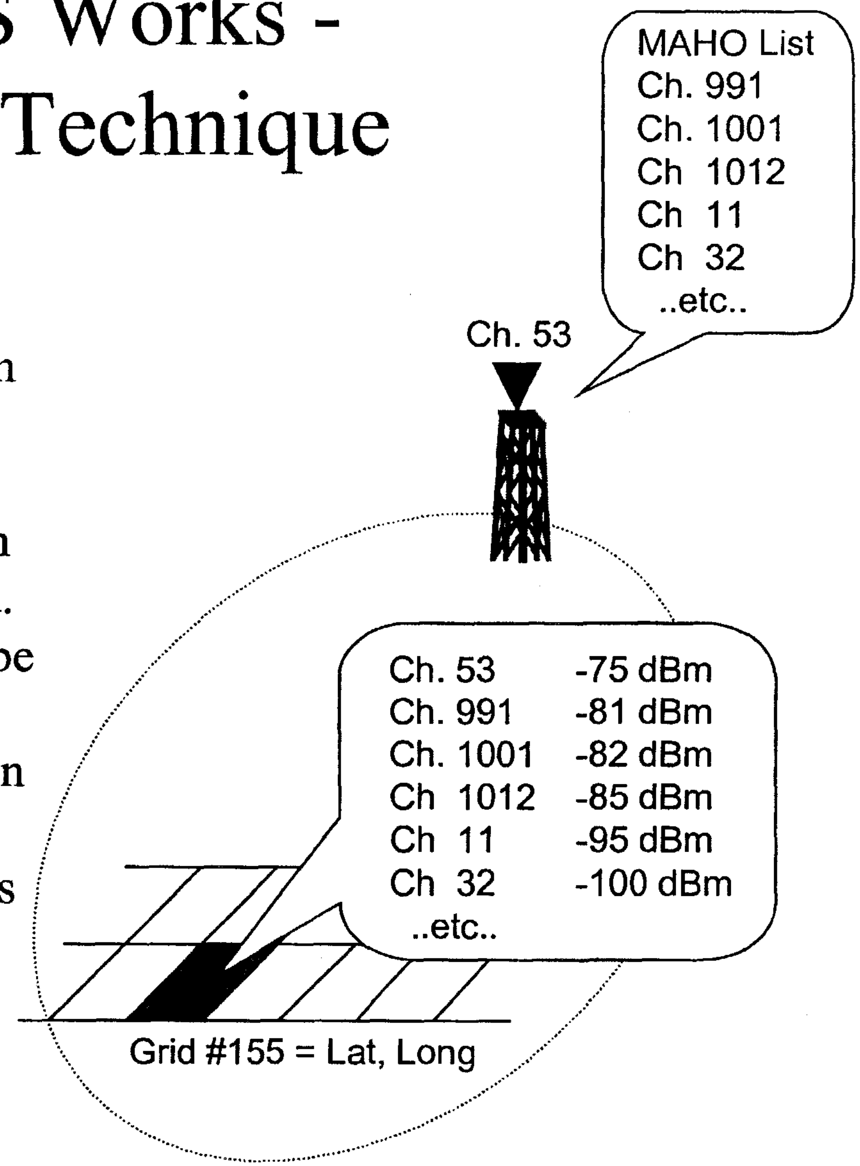
How MNLS Works - MAHO Measurements

1. TDMA asks the mobile to provide information about its current situation to allow for a more efficient handoff process - Mobile Assisted Handoff (MAHO)
2. The MAHO list is comprised of up to 24 neighbor-cell control-channels.
   - MAHO cells are handoff candidates
   -Serving cell broadcasts the MAHO list
1. During calls, the mobile makes signal strength measurements on the serving channel and the MAHO channels
2. The mobile returns these measurements to the MSC continually during the call.
3. The MSC uses these measurements to determine when a cell handoff must occur.
4. MAHO has proven to be very effective and accurate



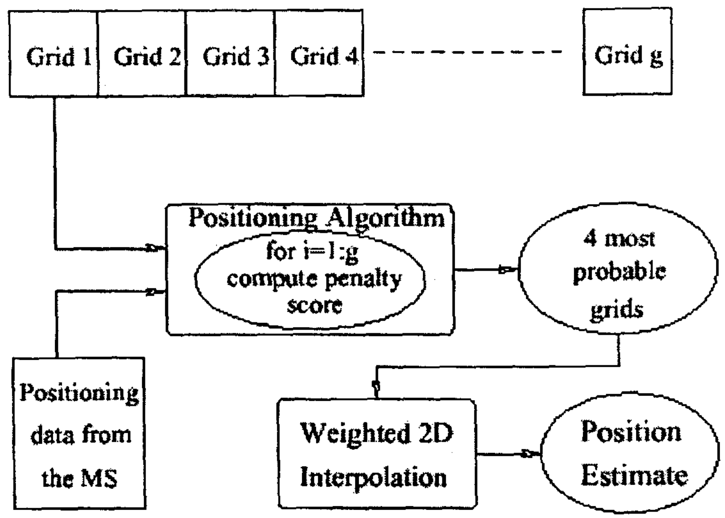
How MNLS Works - System Grid Technique

1. Divide the network into grids for the location database
2. From prediction or measurement data, each grid has an assigned list of channels and signal strengths relationships.
3. The grid channel numbers will be based on the MAHO list of the cell serving that grid.
4. The grid signal strength relationships can be defined in two ways
   (1) Predication -Propagation tool prediction using actual site info.
   (2) Measurement -Drive test measurements with associated location info



How MNLS Works - Position Calculation

1. During a 911 call, reported MAHO measurements are passed to the MPC/PDE.
2. The MPC/PDE receives the signal strength measurements from the MSC and compares them to a stored grid database.
3. Using MNLS algorithms, the appropriate grid location is selected.
4. The MPC returns this position to the PSAP.

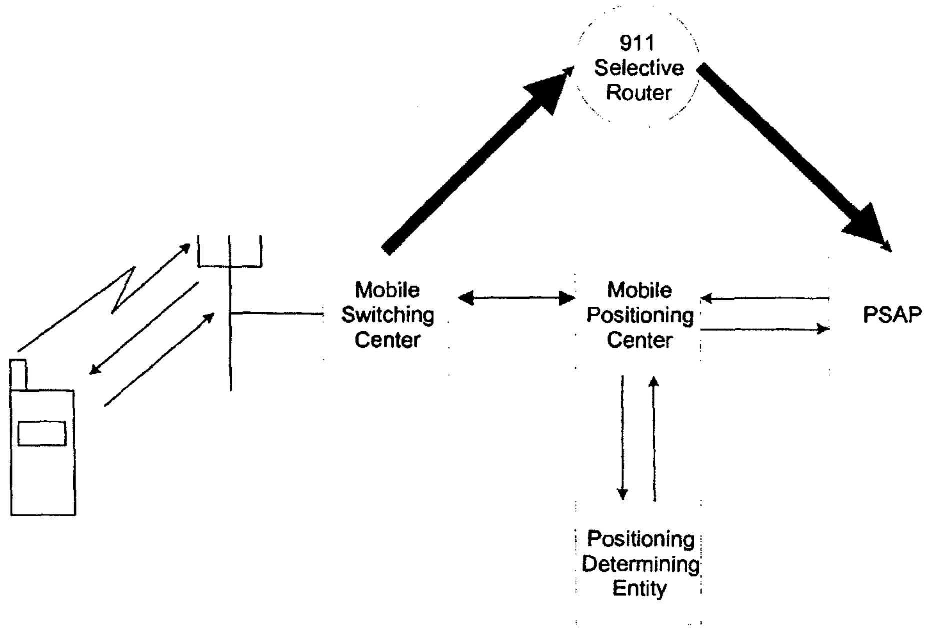


Network Connectivity

- MNLS is fully supported by 911 (J-STD-036) and other wireless standards.

- Allows updated location queries by the PSAP

- Uses E9-1-1 Phase 1 network as the foundation for Phase II with MNLS



AT&T

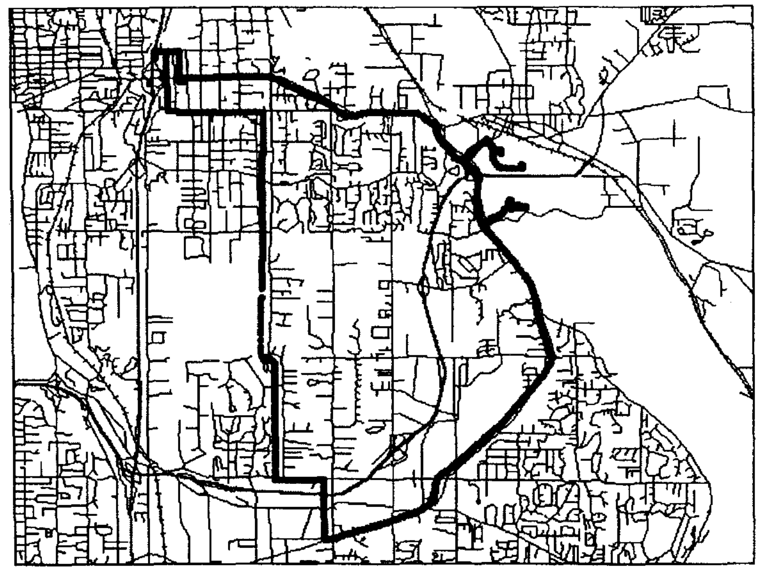
MNLS Advantages for Public Safety

- Superior reliability (due to mainstreaming, with solution integral to overall network operation)
- Swift national deployment, due to ability to implement systemwide, rather than jurisdiction-by-jurisdiction
- Multiple locates ("tracking") can be performed to gain a more accurate location, or monitor movement
- No digital handset replacement or upgrades necessary
- Can perform locates with a single cell site (important for rural areas)
- Based on existing and well known TDMA functionality
- Ubiquitous service to all digital customers (including roamers)
- Consistency with standards: IS-54, IS-136 and J-STD-036
- Use of base station signals (stronger than handset signals) offers advantage in rural areas
- Works for uninitialized phones

Redmond MNLS Trial

•Demonstrated that measured data could be used in combination with predictive data to improve accuracy.

• Proved technology is reliable and robust



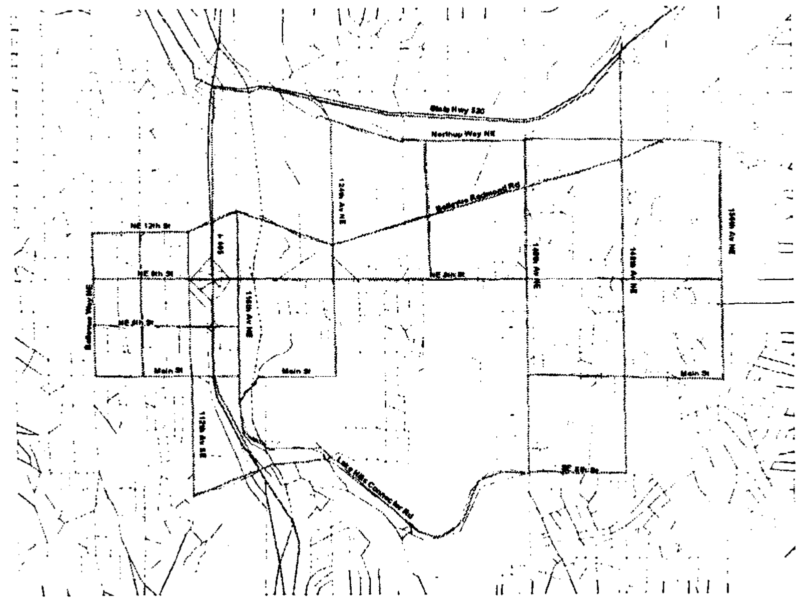
	67%	95%
Drive Test Results	290 meters	606 meters

AT&T

Bellevue MNLS Trial

- Incorporated all types of serving areas: freeways, urban, suburban, rural

- Includes more than 1,900 locates



	67%	95%
Drive Test Results	304 meters	741 meters

AT&T

Paths to Improved MNLS Accuracy

Nature of MNLS lends itself to continuous accuracy improvement:

Data Base Improvements

- Continually increasing use of measured data
- Improve predictive data through tuning of RF propagation models
- Automated drive testing tools

Algorithm Improvements

- New, more intelligent algorithms, (e.g. optimization of sampling)
- Optimized grid selection techniques (possible use of triangulation versus versus contour-matching)
- Optimum grid sizing

Keys to Success

- Commitments (contractual) of infrastructure vendors

- Possible future consideration of use of other technologies to improve accuracy, if necessary

- Partnering with the best, most respected 911 expertise available to help make MNLS successful and meet public safety needs

Intrado's Role and Perspective

- AWS' long-time 911 partner
- Commitment to MNLS success
- Advantages to Public Safety of mainstreaming
- Scaleability issues

AT&T

Discussion

EXHIBIT 3

RECEIVED

DOCKET FILE COPY ORIGINAL

JUL 1 0 2001

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

AT&T

Douglas I. Brandon
Vice President-
External Affairs & Law

AT&T Wireless Services, Inc.
Fourth Floor
1150 Connecticut Ave., N.W.
Washington, DC 20036
202 223-9222
FAX 202 223-9095

July 10, 2001

By Hand
Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 - 12th Street, SW
Washington, DC 20554

Re: AT&T Wireless Services, Inc. - Request for Waiver of the E911 Phase II Location Technology Implementation Rules
CC Docket No. 94-102

Dear Ms. Salas:

Transmitted herewith on behalf of AT&T Wireless Services, Inc. ("AWS") are an original and four copies of the results of AWS's third MNLS field trial in Denver, Colorado, which was referenced in AWS's Partial Response to the Order of the Wireless Telecommunications Bureau filed on May 31, 2001.

Like AWS's Redmond and Bellevue MNLS trials, the Denver trial was designed to test the performance of MNLS technology under the most challenging, real-world conditions, using mobile drive tests and over 2,600 location data points. The report provides a breakdown of both the mobile and stationary performance of MNLS. In conducting the MNLS trial, AWS used the same service footprint as in the Grayson TDOA/AOA trial described in Exhibit E of AWS's April 4 waiver request. The overall accuracy performance for MNLS in the Denver trial was 299 meters 67 percent of the time and 703 meters 95 percent of the time.

If you have any questions concerning this filing, please do not hesitate to contact me.

Respectfully submitted,

Douglas I. Brandon BTB

Douglas I. Brandon

Enclosure
cc: Kris Monteith
Blaise Scinto
James Schlichting
Jennifer Tomchin

No. of Copies rec'd 0+4
List ABCDE

WDC 217621v1
Recycled Paper

AT&T Wireless Services, Inc.

Denver MNLS Trial
Technical Summary

Phase 2: E911 Location Technology Trial

Document Number	**10998**
Revision	**1.0**
Revision Date	**07/03/01**

Technology Development Group
Base Station Development
AT&T Wireless Services, Inc.
PO Box 97061
Redmond, WA 98073

Contents

Figures

Tables

1. Purpose

The FCC specifies an October 2001 deadline for providing location-based capability for wireless services. That time limit—for Phase II of the FCC's enhanced 911 (E911) order of 1996—requires that each wireless telecommunications company doing business in the United States must offer either handset- or network-based location detection capability. The FCC requires that network-based systems must be accurate within 100 meters for 67 percent of calls and within 300 meters for 95 percent of calls.

This document provides a technical summary of the drive-test efforts and analysis performed for the E911 Mobile Network Location System (MNLS) trial performed in Redmond, WA in 2001.

1. Overview

1.1. Introduction

Positioning technologies for cellular systems may be differentiated based on the types of measurements made. The most common measurements involve analysis of the radio signal transmitted or received by the mobile terminal to be positioned. These analyses are:

- Time of arrival (TOA).
- Time difference of arrival (TDOA).
- Angle of arrival (AOA).
- Received signal strength (RSS).

An RSS-based positioning technique referred to as Mobile Network Location System (MNLS) has been proposed for positioning in TDMA networks. In this technique, RSS measurements are made by the mobile terminal on downlink channels from the serving and neighboring base stations. These RSS measurements are then used by the Position Determining Equipment (PDE) in the cellular network to calculate the position of the mobile terminal, given knowledge of the transmitted powers from the base stations, the locations of the base stations, and the sector layout in the coverage area.

In TDMA systems, the mobile terminal can be ordered to make RSS measurements when it is camping on the control channel and when it is on a traffic channel. In the former case, RSS measurements are used for mobile-assisted channel allocation (MACA); in the latter case, RSS measurements are used for mobile-assisted handoff (MAHO). The advantage of MNLS is that TDMA digital cellular standards already call for the mobile terminal to make RSS measurements for network management reasons; therefore the MNLS method has minimal impact on TDMA digital cellular standards.

This document describes the performance of the MNLS method in a TDMA network. Measurements were made in the Denver, CO market.

First, a set of RSS measurements on downlink channels was used to construct a database at different positions within the coverage area. A second set of RSS measurements was then used to test positioning performance of MNLS in the test area.

Section 1.2 describes the measurement and prediction data in greater detail. Section 2 discusses the MNLS performance. Conclusions are presented in Section 3.

1.2. Field Measurements

Field measurements were conducted by AT&T Wireless in the Denver market using an Ericsson T-18D TEMS (Test Mobile System) mobile phone, a computer with TEMS software for logging phone measurement data, and a GPS (Global Positioning System) receiver.

Measurements were made in idle mode of the RSS downlink channels of the serving and neighbor cells. The TEMS software logged both the RSS measurements and GPS position data.

The RSS/GPS measurements were then used to create a database for the coverage area. The database grid size was 50 meters.

Similar measurements were then made in idle mode of the RSS downlink channels of the serving and neighbor cells. Typically the measurements would have been made on an active call. However, due to the use of Forward Power Control (FPC) and Mobile Switching Center (MSC) software that currently allows 12 neighbors, collecting active call information was not possible.

When the MSC software in the Denver market is upgraded in the near future to allow 24 neighbors, the serving site's control channel can be included in the neighbor list. This allows measurements to be made on the serving cell without any power reduction due to FPC. Control channels are not included in FPC, as any power reduction would negatively impact call setup.

MNLS position was calculated using the database created from the idle mode measurements. Every four measurements were used together for MNLS calculation purposes. The TEMS mobile phone reports MAHO scans every 1.28 seconds. Therefore, an MNLS position was provided about every five seconds.

Position error was determined using the first of the five GPS positions. Care was taken to verify all five of the GPS/RSS measurements were within 50m of each other.

Figure 1 through Figure 4 show the results of each of the drive routes. Figure 5 shows the results of the six stationary test points.

Figure 1 Measurements Made on Freeway Routes I-70 and I-25

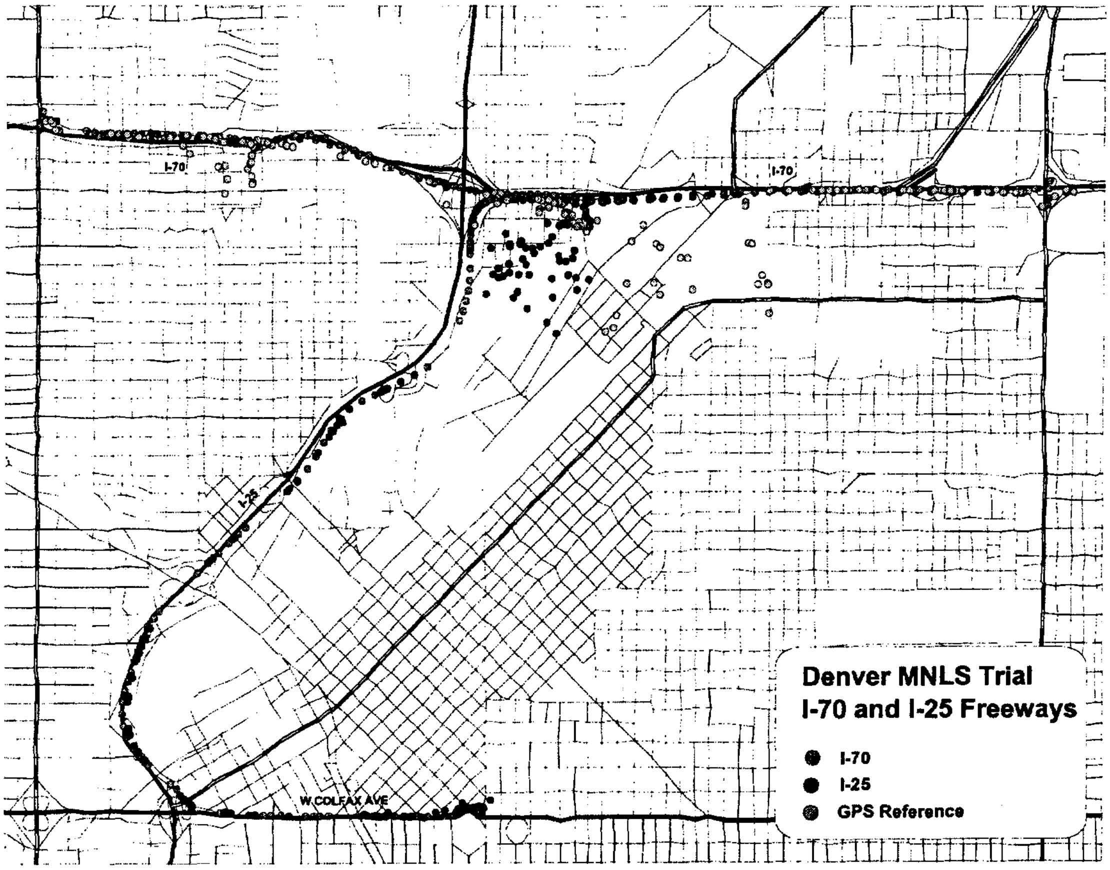


Figure 2 Dense Urban Route 1

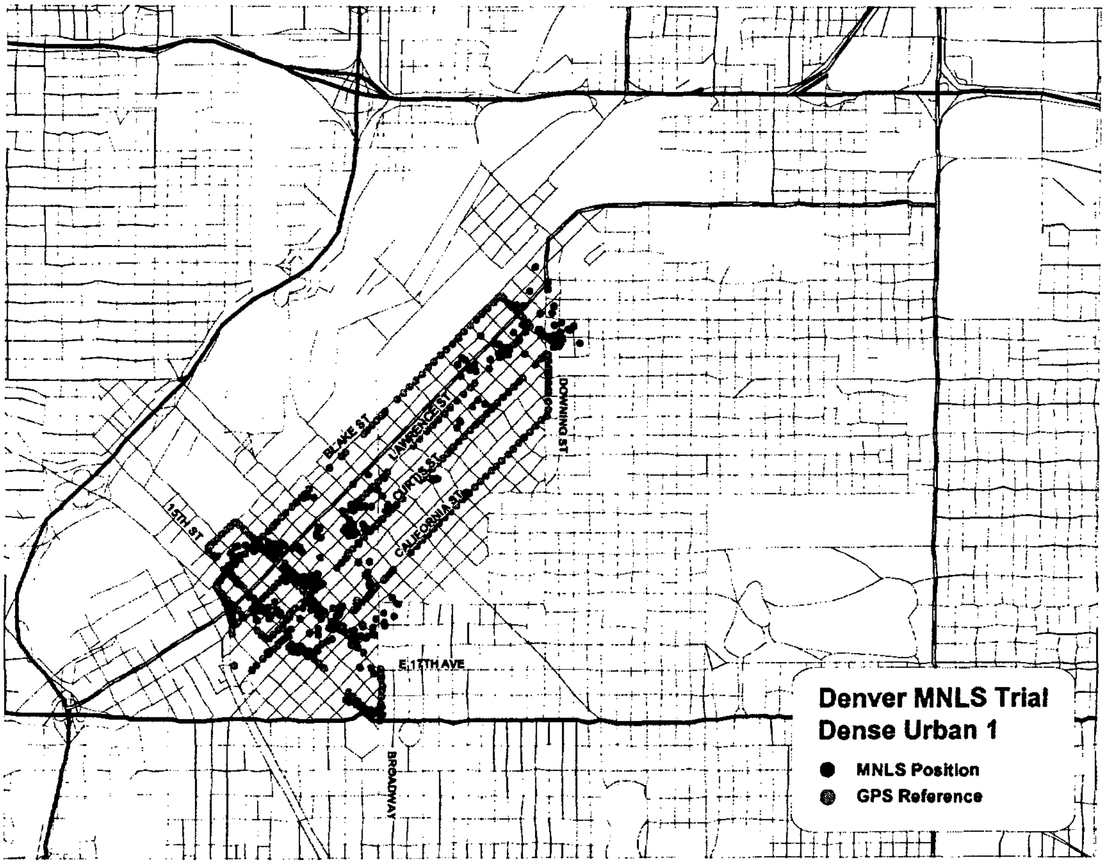


Figure 3 Dense Urban Route 2

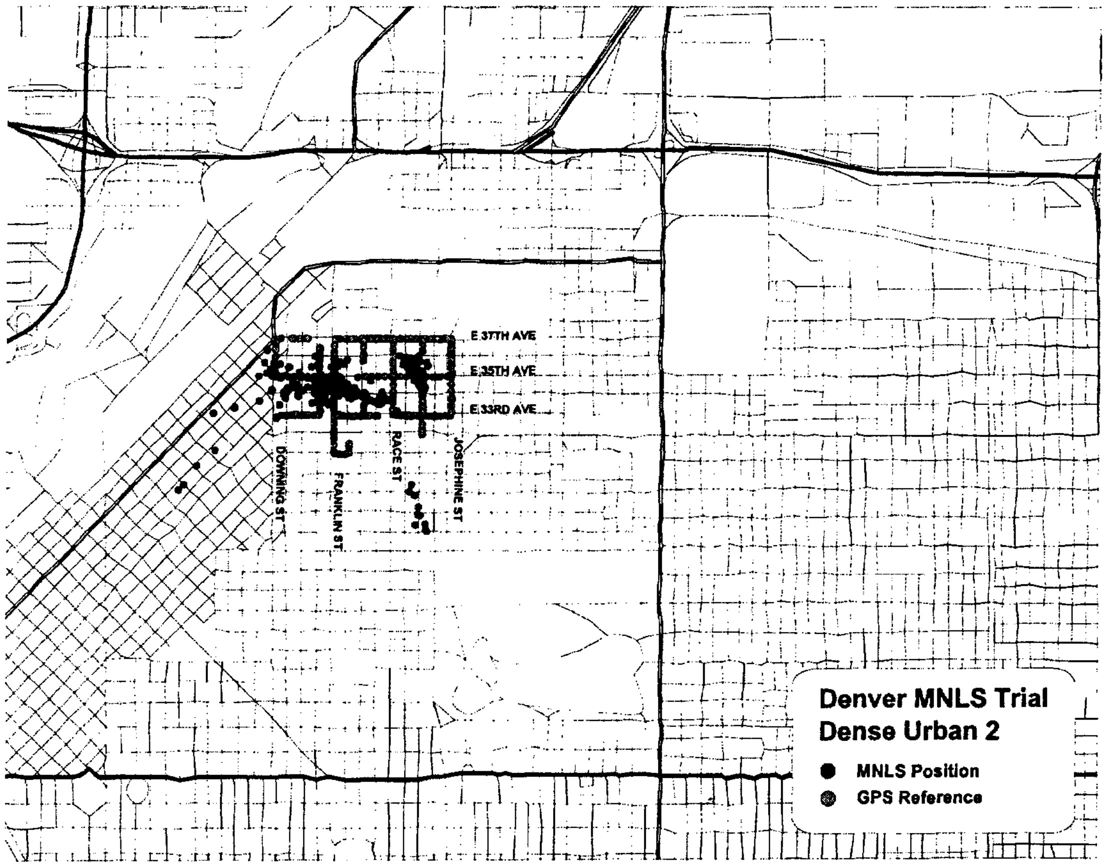


Figure 4 Dense Urban Route 3

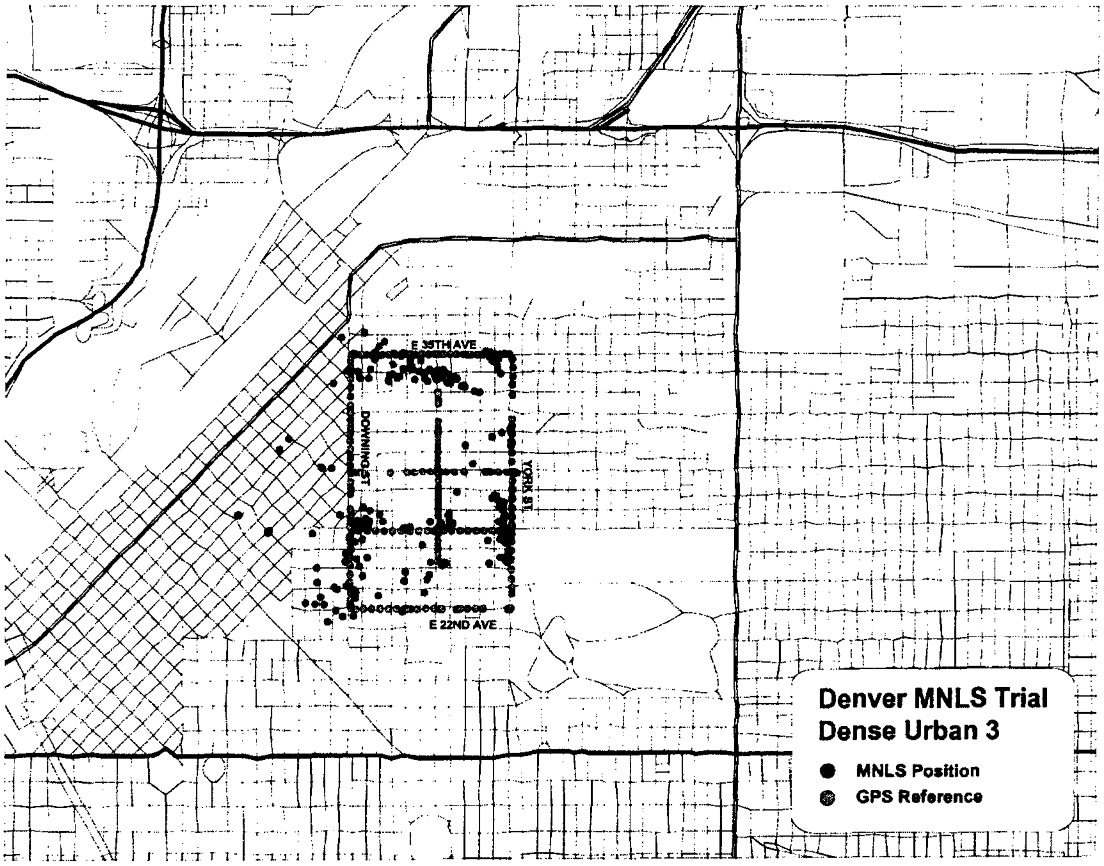


Figure 5 Urban Route

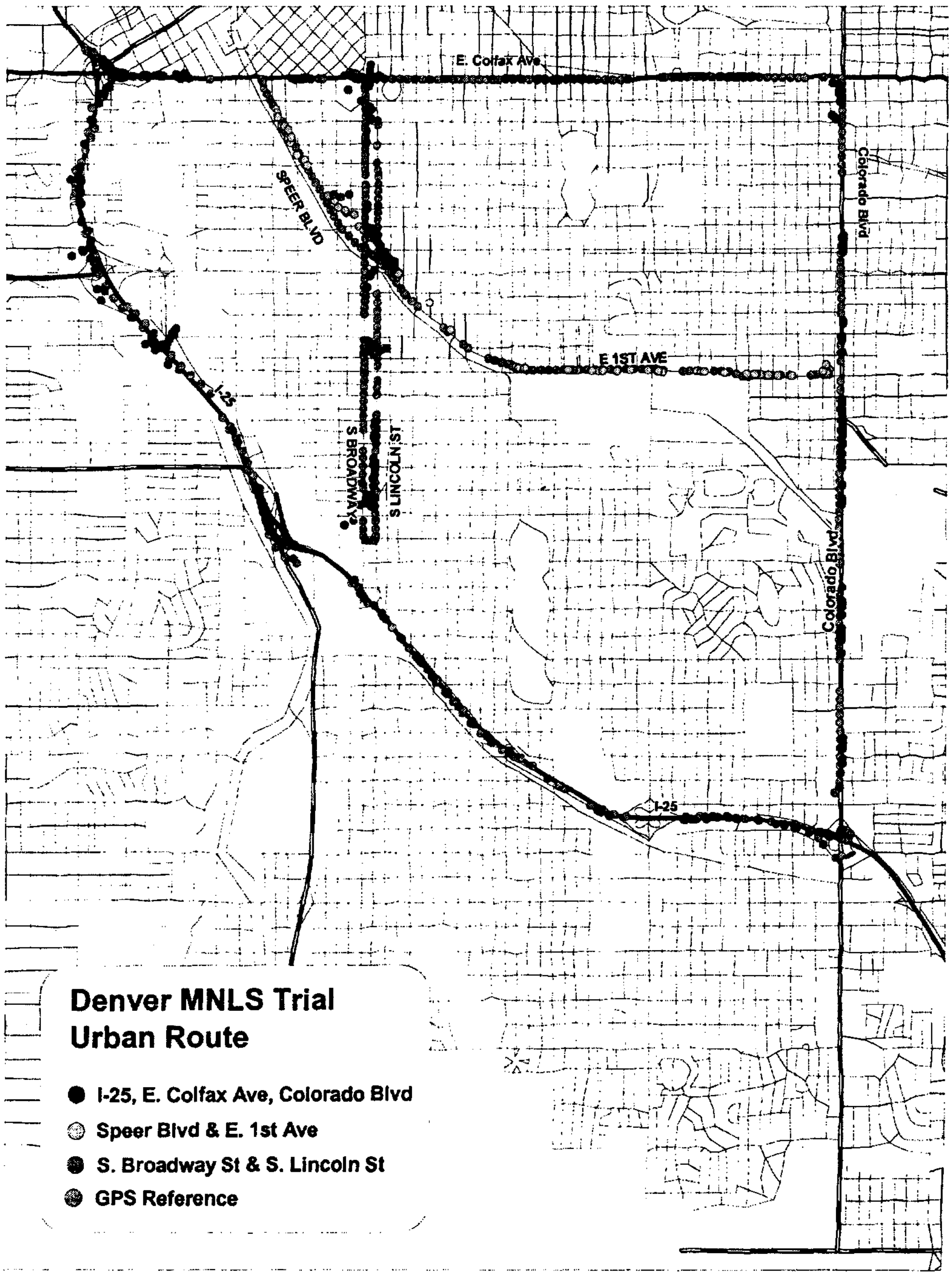


Figure 6 Suburban Route

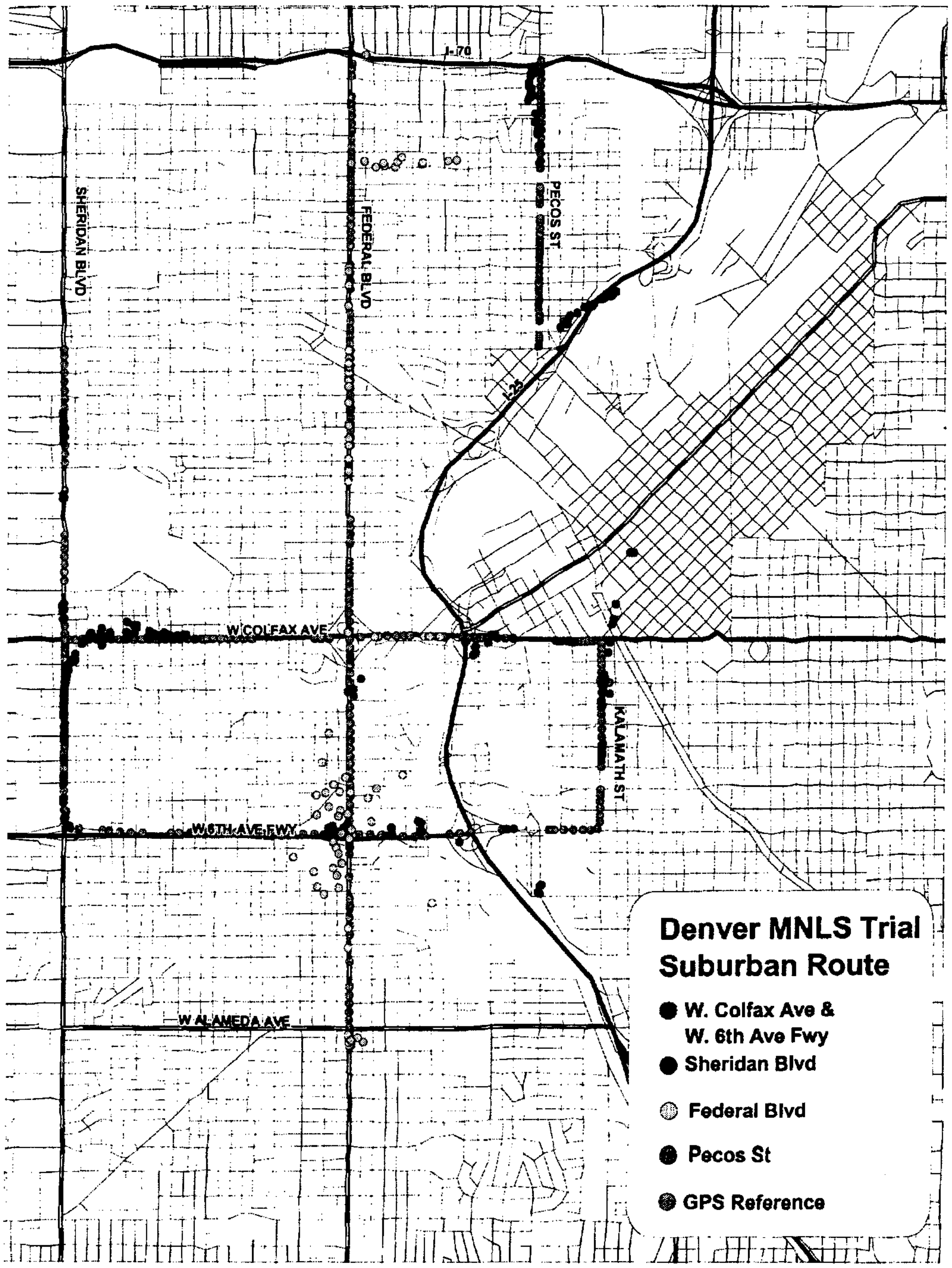
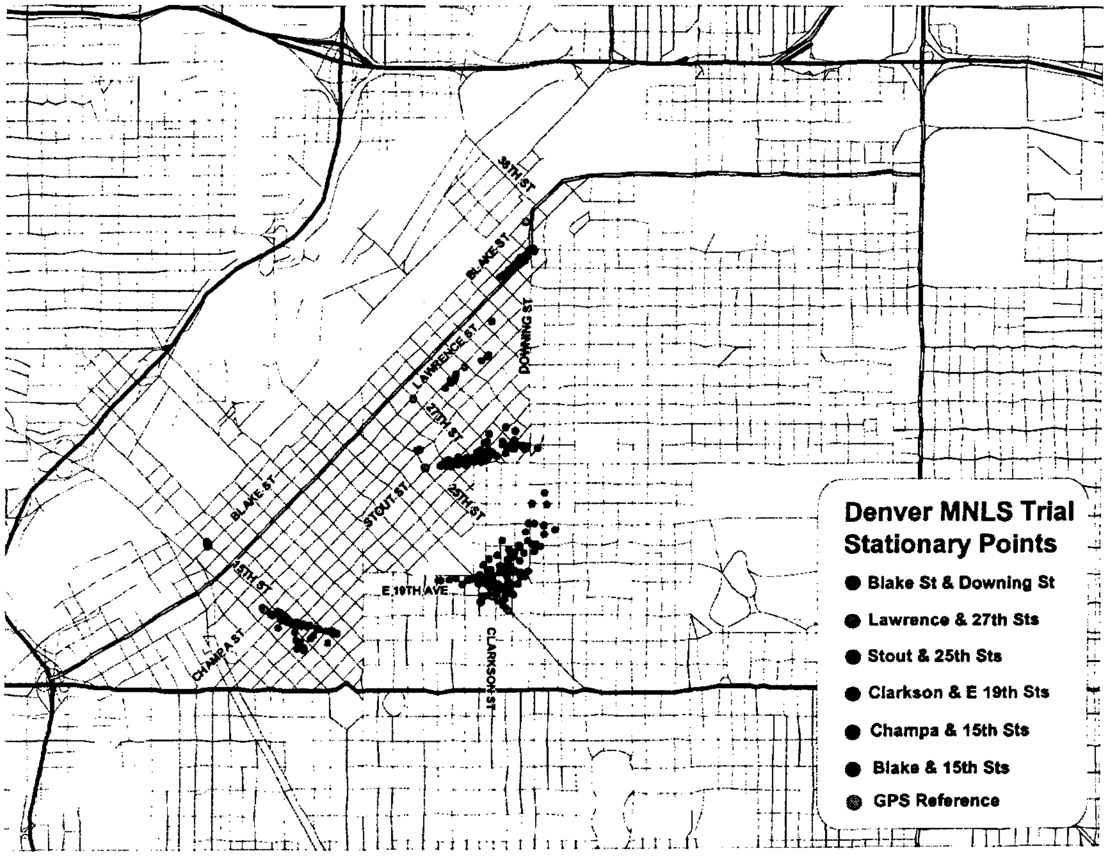


Figure 7 Stationary Test Points



2. MNLS Performance

Table 1 summarizes MNLS position errors measured in this trial (expressed as percentages).

Table 1 Denver MNLS Trial Position Errors

Trial Position Location	Probability		Number of Measurements
	67%	95%	
Total Aggregate Position Error	299 m	703 m	2611
Total Aggregate Drive Position Error	285 m	716 m	2244
Total Aggregate Stationary Position Error	351 m	650 m	367

2.1. Performance Improvements

2.1.1. Grid Size

In general, smaller grid sizes are expected to provide better performance and the choice of grid size should be based on the expected performance with a certain database. In order to ensure the best possible performance with a given database, a grid size in the range of 50 meters is recommended.

2.1.2. Database Quality

In order to improve the performance of MNLS in the future, the main factor to be targeted is the quality of the database. Database quality may be improved in the following ways:

- More accurate RF propagation models will improve the quality of the prediction data.
- Measurement data over the whole coverage area is expected to have better quality than prediction data and, if available, could be used to build the database.
- Periodic testing of a database built from prediction data could be used to determine which regions and/or channels have the

poorest quality, and the corresponding data can be replaced or augmented with measurement data. That is, a hybrid database that includes both prediction data and measured data can be used.

- A smaller grid size can be used for regions in the densely-populated coverage areas.
- Extra information, such as map data for the coverage area, may be used to reduce the number of possible location estimates and thus improve performance.
- Use of a dead reckoning positioning system would improve measurements collected in poor GPS reception areas.

Note: The databases used to generate results in this document were generated for the purpose of a field trial only. The database generated from measurements could have been enhanced with measurements gathered with more density.

3. Conclusions

An averaging time of approximately five seconds was used for processing measurements. This averaging time was chosen considering the tradeoff between the delay incurred in calculating position and the quality of the measurement sample used. A grid size of 50 meters was used to provide the best results with the given data. See Table 1 for overall results.